CLAIMS

1.   A forced-air heater control system for an electric heater having at least one electric heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, the control system comprising:

a first temperature sensor and second temperature sensor respectively disposed upstream and downstream of, and spaced equidistant from, said at least one heating element, each said temperature sensor producing an output therefrom;

a control signal generator accepting said temperature sensor outputs and outputting a power ON signal to said power control switch when the difference between said temperature sensor outputs is below a predetermined value.

2.   A forced-air heater control system as claimed in claim 1 wherein said first and second temperature sensor are first and second thermistors which are spaced from said at least one heating element such that said thermistors are capable of sensing the radiant heat from said at least one heating element.

3.   A forced-air heater control system as claimed in claim 1 wherein said control signal generator includes a means for outputting a power OFF signal to said power control switch when either one of said first and second temperature sensor outputs reaches a predetermined maximum value.

4.   A forced-air heater control system as claimed in claim 3 wherein said means for outputting a power OFF signal includes one of a digital means and an analog means.

5.   A forced-air heater control system as claimed in claim 1 wherein said control signal generator includes means for generating a pulse width modulated signal to generate said power ON signal when the difference between said temperature sensor outputs is below a predetermined value.

6.   A forced-air heater control system as claimed in claim 5 wherein said means for generating a pulse width modulated signal includes one of a digital means, binary means and an analog means.

7.   A forced-air heater control system as claimed in claim 1 wherein said control signal generator includes means for generating a pulse width modulated signal to generate said power ON signal when the difference between said temperature sensor outputs is below a predetermined value, wherein said electrical power supplied to said at least one electric heating element is an alternating current power supply, and said pulse width modulated signal is correlated to said alternating current power supply.

8.   A forced-air heater control system as claimed in claim 1 wherein said control signal generator includes means for generating a pulse width modulated signal to generate said power ON signal when the difference between said thermistor outputs is below a predetermined value, wherein said electrical power supplied to said at least one electric heating element is a DC power supply, and said pulse width modulated signal controls said DC power supplied to said at least one heating element.

9.   A forced-air heater control system as claimed in claim 1 wherein said control signal generator is coupled to said power control switch of said at least one electric heating element via at least one opto-isolator.

10.   A forced-air heater control system as claimed in claim 1 wherein said power switch is a triac or solid state relay (SSR).

11. A forced-air heater control system for an electric heater having at least one electric heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, the control system comprising:

an upstream temperature sensor and a downstream temperature sensor, said upstream and downstream temperature sensor being a thermistor or a resistive temperature detector (RTD), said respective temperature sensors being disposed equidistant from said at least one electric heating element within said duct, and each said temperature sensor having a respective electrical output;

a control circuit accepting as inputs said respective electrical outputs of said temperature sensors, said control circuit including means for obtaining a difference between the output of said upstream temperature sensor and the output of said downstream temperature sensor, said control circuit generating a difference signal which represents convection heat sensed by said downstream temperature sensor, said control circuit including means for generating a pulse width modulated signal based upon said difference signal;

a communicative coupling between said control circuit and said power control switch such that said pulse width modulated signal controls are applied to said electrical power supplying power to said at least one electric heating element.

12. A forced-air heater control system as claimed in claim 11 wherein said communicative coupling is an opto-isolator.

13. A forced-air heater control system as claimed in claim 11 wherein said power control switch is a triac or solid state relay.

14. A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, the method comprising:

sensing the heat in the air duct at equidistant upstream and downstream locations relative to said at least one electric heating element;

comparing the heat sensed at said equidistant upstream and downstream locations to obtain a difference signal; and

enabling said power control switch to supply said electrical power when said difference signal is below a predetermined value.

15. The method of claim 14 wherein said enabling step includes the step of generating a pulse width modulated signal based upon said difference signal.

16. The method of claim 14 wherein said comparing step includes the step of comparing said heat sensed at said equidistant upstream and downstream locations to a maximum threshold value, respectively, and disabling said power control switch if either of said heat sensed exceeds said value.

17. A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, the method comprising:

sensing an upstream temperature and a downstream temperature in the air duct at respective upstream and downstream positions relative to said at least one electric heating element such that said

upstream and downstream temperatures are effected by radiant heat directly developed by said at least one heating element;

determining an air velocity through said air duct;

determining the amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream and downstream temperatures; and

enabling said power control switch to supply said electrical power when said kilowatts (KW) or other heat per unit time or power is less than a predetermined value.

18.   A method as claimed in claim 17 wherein said predetermined value is the maximum designed kilowatts (KW) or other heat per unit time or power for said air duct.

19.   A method as claimed in claim 17 including determining a respective radiant heat temperature factor for said upstream and downstream temperatures, based upon said electrical power supplied to said at least one heating element and the distance of the respective upstream and downstream positions, and adjusting said upstream and downstream temperatures with said respective radiant heat temperature factor prior to determining the amount of kilowatts (KW) or other heat per unit time or power.

20.   A method as claimed in claim 17 wherein said upstream and downstream positions are equidistant from said at least one heating element.

21.   A method as claimed in claim 17 wherein determining said air velocity includes obtaining a thermal anemometric measurement of airflow in said duct.

22.   A method as claimed in claim 21 including compensating said thermal anemometric measurement by sensing an ambient temperature in said air duct proximal said thermal anemometric measurement.

23.   A method as claimed in claim 17 wherein determining air velocity includes sensing a differential pressure in said air duct, said differential pressure base upon a total pressure and a static pressure.

24.   A method as claimed in claim 23 said total pressure and said static pressure is sensed either in said air duct or in a sub-system of said air duct subject to the same pressures as said air duct.

25.   A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, the method comprising:

    sensing an upstream temperature in the air duct at said upstream position relative to said at least one electric heating element such that said upstream temperature is effected by radiant heat directly developed by said at least one heating element, providing a downstream temperature having a predetermined, pre-set value;

    determining an air velocity through said air duct;

    determining the amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream and downstream temperatures; and

    enabling said power control switch to supply said electrical power when said kilowatts (KW) or other heat per unit time or power is less than a predetermined power value.

26.   A method as claimed in claim 25 including determining a radiant heat temperature factor for said upstream temperature, based upon said electrical power supplied to said at least one heating element and the distance of the upstream position, and adjusting said upstream temperature with said

34

radiant heat temperature factor prior to determining the amount of kilowatts (KW) or other heat per unit time or power.

27. A method as claimed in claim 25 wherein determining said air velocity includes obtaining a thermal anemometric measurement of airflow in said duct.

28. A method as claimed in claim 27 including compensating said thermal anemometric measurement by sensing an ambient temperature in said air duct proximal said thermal anemometric measurement.

29. A method as claimed in claim 25 wherein determining air velocity includes sensing a differential pressure in said air duct, said differential pressure base upon a total pressure and a static pressure.

30. A method as claimed in claim 29 said total pressure and said static pressure is sensed either in said air duct or in a sub-system of said air duct subject to the same pressures as said air duct.

31. A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air, said at least one electric heating element supplied with electrical power via a power control switch, the method comprising:

sensing temperatures in said air duct on either side of said at least one electric heating element and determining an upstream temperature and a downstream temperature which temperatures are directly effected by radiant heat developed by said at least one heating element;

determining an air velocity through said air duct;

determining the amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream and downstream temperatures; and

35

enabling said power control switch to supply said electrical power when said kilowatts (KW) or other heat per unit time or power is less than a predetermined value.

32.   A method as claimed in claim 31 including determining a respective radiant heat temperature factor for said upstream and downstream temperatures, based upon said electrical power supplied to said at least one heating element and the distance of the respective upstream and downstream positions, and adjusting said upstream and downstream temperatures with said respective radiant heat temperature factor prior to determining the amount of kilowatts (KW) or other heat per unit time or power.

33.   A method as claimed in claim 31 wherein said upstream and downstream positions are equidistant from said at least one heating element, and said predetermined value is the maximum design value for said air duct.

34.   A method as claimed in claim 31 wherein determining said air velocity includes obtaining a thermal anemometric measurement of airflow in said duct.

35.   A method as claimed in claim 34 including compensating said thermal anemometric measurement by sensing an ambient temperature in said air duct proximal said thermal anemometric measurement.

36.   A method as claimed in claim 31 wherein determining air velocity includes sensing a differential pressure in said air duct, said differential pressure base upon a total pressure and a static pressure.

37.   A method as claimed in claim 36 said total pressure and said static pressure is sensed either in said air duct or in a sub-system of said air duct subject to the same pressures as said air duct.

38. A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air, said at least one electric heating element supplied with electrical power via a power control switch, the method comprising:

sensing temperatures in said air duct on either side of said at least one electric heating element and determining an upstream temperature which is directly effected by radiant heat developed by said at least one heating element; providing a downstream temperature having a predetermined, pre-set value;

determining an air velocity through said air duct;

determining the amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream and said pre-set downstream temperature value; and

enabling said power control switch to supply said electrical power when said kilowatts (KW) or other heat per unit time or power is less than a predetermined power value.

39. A method as claimed in claim 38 including determining a radiant heat temperature factor for said upstream temperature, based upon said electrical power supplied to said at least one heating element and the distance of the upstream position, and adjusting said upstream temperature with said radiant heat temperature factor prior to determining the amount of kilowatts (KW) or other heat per unit time or power, said predetermined power value is a maximum design value.

40. A method as claimed in claim 38 wherein determining said air velocity includes obtaining a thermal anemometric measurement of airflow in said duct.

41. A method as claimed in claim 40 including compensating said thermal anemometric measurement by sensing an ambient temperature in said air duct proximal said thermal anemometric measurement.

37

42. A method as claimed in claim 38 wherein determining air velocity includes sensing a differential pressure in said air duct, said differential pressure base upon a total pressure and a static pressure.

43. A method as claimed in claim 42 said total pressure and said static pressure is sensed either in said air duct or in a sub-system of said air duct subject to the same pressures as said air duct.

44. A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, said air duct having a predetermined set point temperature, the method comprising:

sensing an upstream temperature and a downstream temperature in the air duct at respective upstream and downstream positions relative to said at least one electric heating element such that said upstream and downstream temperatures are effected by radiant heat directly developed by said at least one heating element;

determining an air velocity through said air duct based upon said upstream and downstream temperatures;

determining an amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream temperature;

enabling said power control switch to supply said electrical power based upon said kilowatts (KW) or other heat per unit time or power.

45.   A method of controlling a forced-air heater system as claimed in claim 44 including re-determining said air velocity with said kilowatts (KW) or other heat per unit time or power and said upstream and downstream temperatures when a comparison of said downstream temperature and said set point temperature is beyond a predetermined range.

46.   A method of controlling a forced-air heater system as claimed in claim 44 including:

enabling said power control switch to supply said electrical power to said at least one heating element with a known power ON signal at least during one of a start up time and a time when said velocity, as determined by said determining air velocity, is less than a nominal value; and

re-determining said air velocity based upon said kilowatts (KW) or other heat per unit time or power of said nominal power ON signal and said upstream and downstream temperatures.

47.   A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, said air duct having a predetermined set point temperature, the method comprising:

sensing an upstream temperature and a downstream temperature in the air duct at respective upstream and downstream positions relative to said at least one electric heating element such that said upstream and downstream temperatures are effected by radiant heat directly developed by said at least one heating element;

determining an air velocity through said air duct;

determining an amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream temperature;

39

enabling said power control switch to supply said electrical power based upon said kilowatts (KW) or other heat per unit time or power; and

re-determining said air velocity with said kilowatts (KW) or other heat per unit time or power and said upstream and downstream temperatures when a comparison of said downstream temperature and said set point temperature is beyond a predetermined range.

48.   A method of controlling a forced-air heater system as claimed in claim 47 including:

enabling said power control switch to supply said electrical power to said at least one heating element with a known power ON signal at least during one of a start up time and a time when said velocity, as determined by said determining air velocity, is less than a nominal value; and

re-determining said air velocity based upon said kilowatts (KW) or other heat per unit time or power of said known power ON signal and said upstream and downstream temperatures.

49.   A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, said air duct having a predetermined set point temperature, the method comprising:

sensing an upstream temperature and a downstream temperature in the air duct at respective upstream and downstream positions relative to said at least one electric heating element;

determining an air velocity through said air duct with said upstream and downstream temperatures;

determining an amount kilowatts (KW) or other heat per unit time or power based upon said velocity and said upstream temperature;

enabling said power control switch to supply said electrical power based upon said kilowatts (KW) or other heat per unit time or power.

50.   A method of controlling a forced-air heater system having at least one heating element disposed within an air duct carrying forced air from an upstream position to a downstream position, said at least one electric heating element supplied with electrical power via a power control switch, said air duct having a predetermined set point temperature, the method comprising:

sensing an upstream temperature and a downstream temperature in the air duct at respective upstream and downstream positions relative to said at least one electric heating element such that said upstream and downstream temperatures are effected by radiant heat directly developed by said at least one heating element;

determining an air velocity through said air duct;

determining an amount kilowatts (KW) or other heat per unit time or power based upon said velocity and one of said upstream temperature, said downstream temperature and said set point temperature;

enabling said power control switch to supply said electrical power based upon said kilowatts (KW) or other heat per unit time or power; and

re-determining said air velocity with said kilowatts (KW) or other heat per unit time or power and said upstream and downstream temperatures upon occurrence of a trigger point control.

51.   A method of controlling a forced-air heater system as claimed in claim 50 wherein said trigger pont control is one of a time out function and a temperature differential function.

41

52.   A method of controlling a forced-air heater system as claimed in claim 51 wherein said

temperature differential function is based up one of said upstream temperature, said downstream

temperature and said set point temperature compared to an acquired signal.

53.   A method of controlling a forced-air heater system as claimed in claim 52 wherein said

acquired signal one or the other of said sensed upstream temperature and downstream temperature which

creates said differential function.

54.   A method of controlling a forced-air heater system as claimed in claim 50 including:

enabling said power control switch to supply said electrical power to said at least one heating

element with a known power ON signal at least during one of a start up time and a time when said velocity,

as determined by said determining air velocity, is less than a nominal value; and

re-determining said air velocity based upon said kilowatts (KW) or other heat per unit time or

power of said known power ON signal and said upstream and downstream temperatures.